
HTML5-based Visualizations to Support Software Fault Isolation

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Co-Supervisor: *José Carlos de Campos (MSc)*

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1. Context and Objectives

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Objectives

2. Software
Visualizations

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Visualizations

Visual Debugging Tools

- GZoltar

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Efficiency of Visualizations

Usability of GZoltar

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Context

- GZoltar is a framework for automating the testing and debugging phase;
- Two OpenGL-based visualizations were implemented:
 - The implementation had some optimization issues;
 - OpenGL has some compatibility problems with certain drivers.



Debugging



Objectives

OpenGL replaced with HTML5



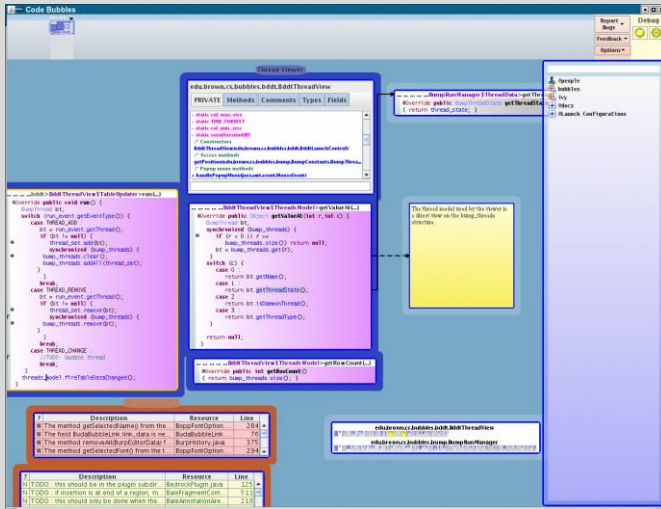
Objectives

OpenGL replaced with HTML5

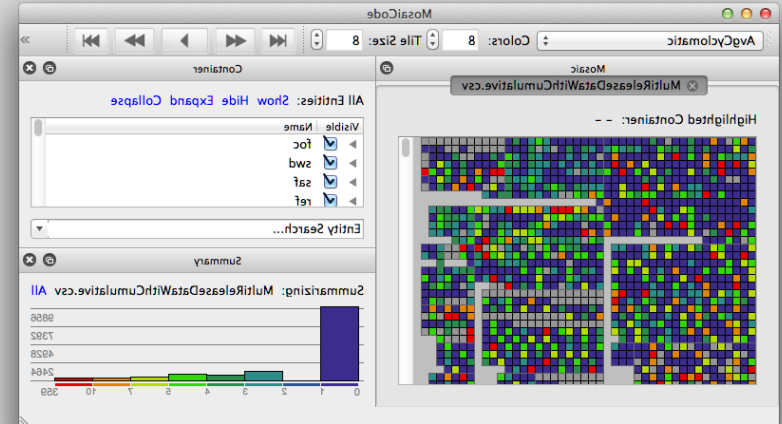


User Study

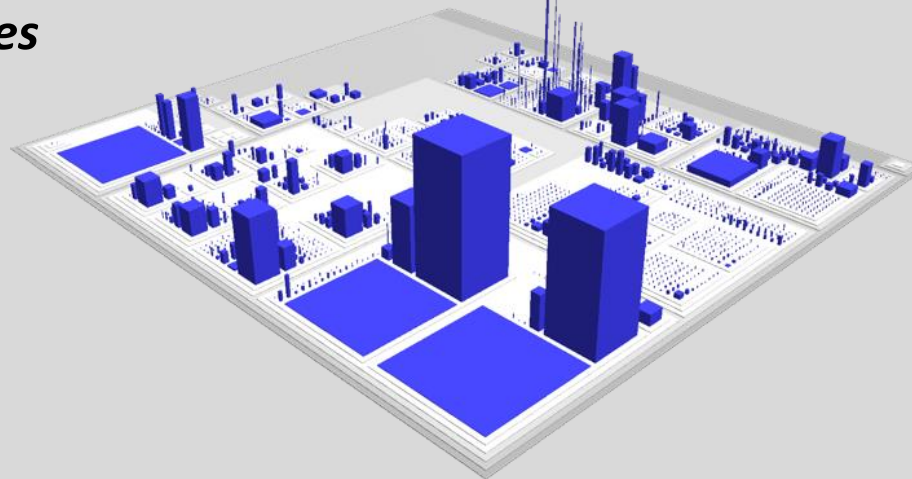
Software Visualizations



Code Bubbles

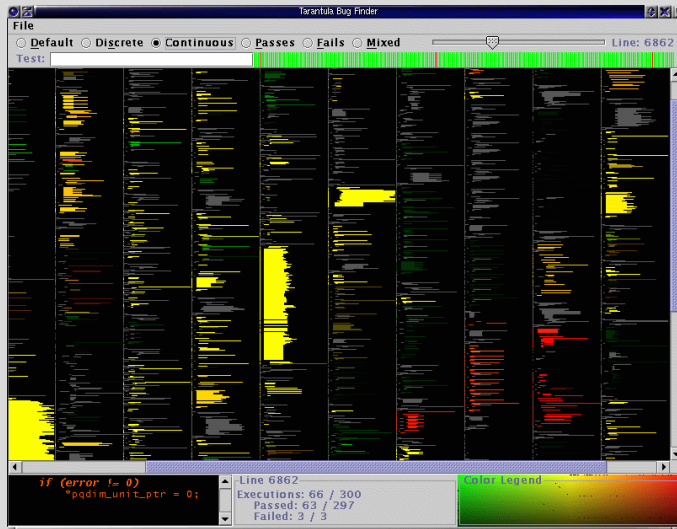


MosaiCode

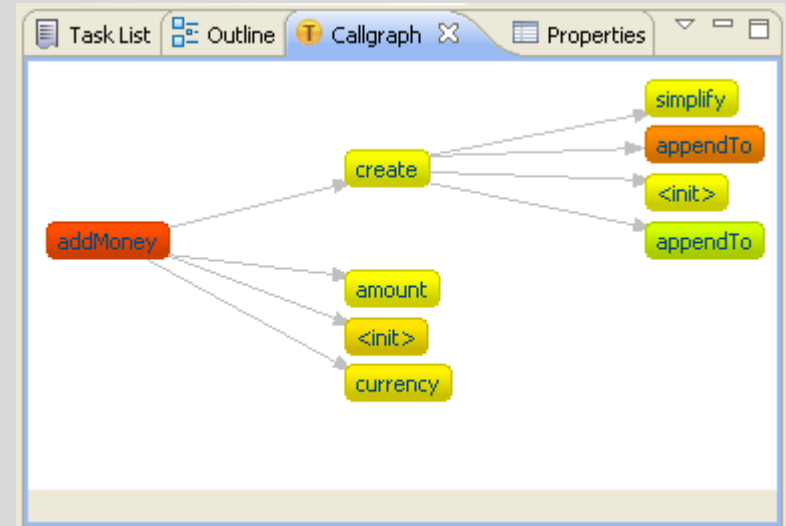


CodeCity

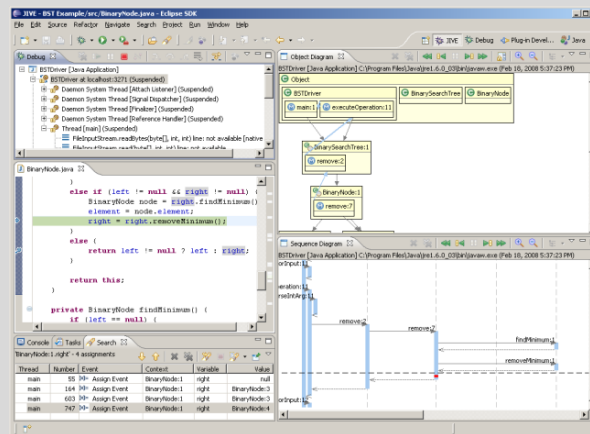
Visual Debugging Tools



Tarantula

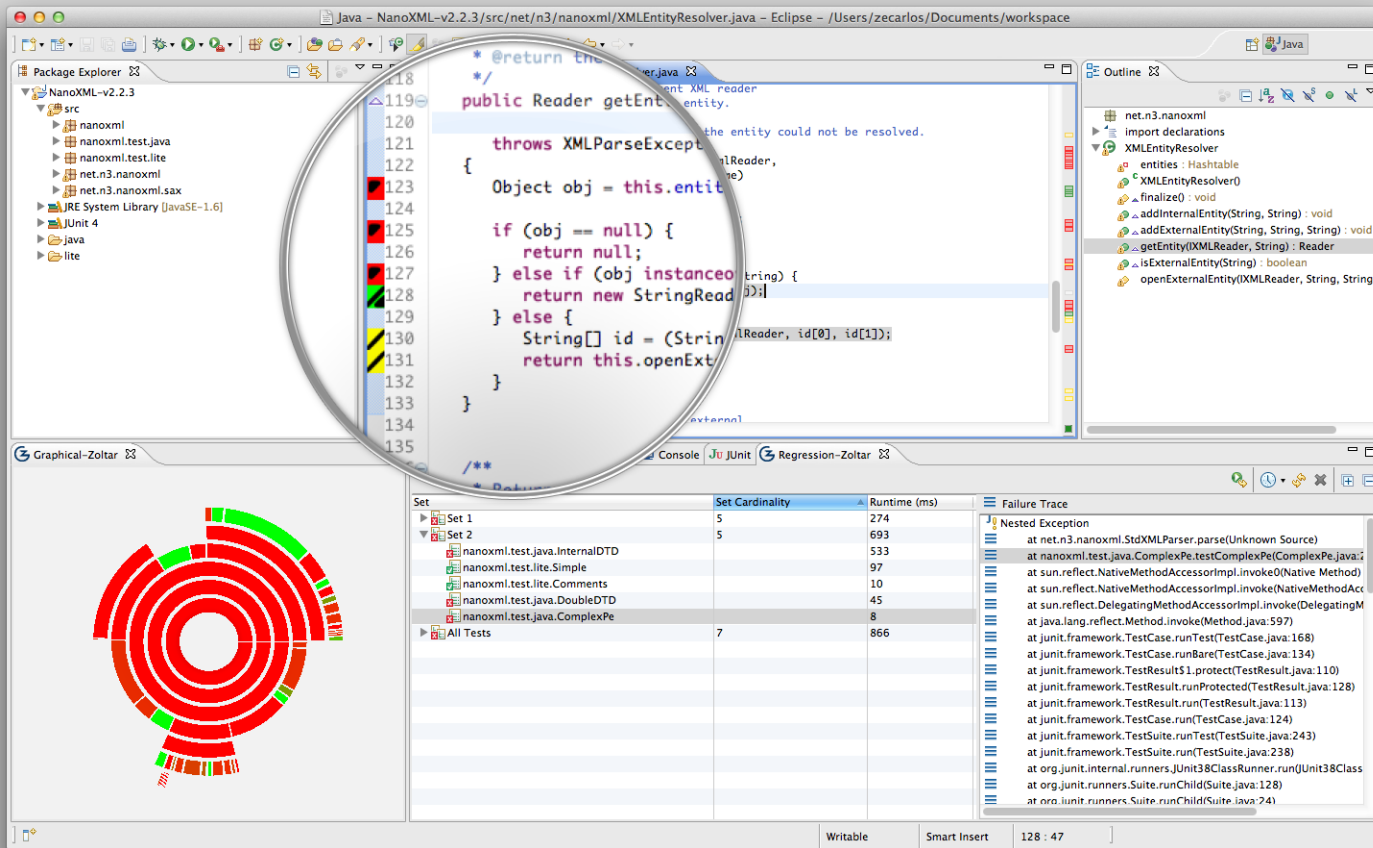


EzUnit




JIVE

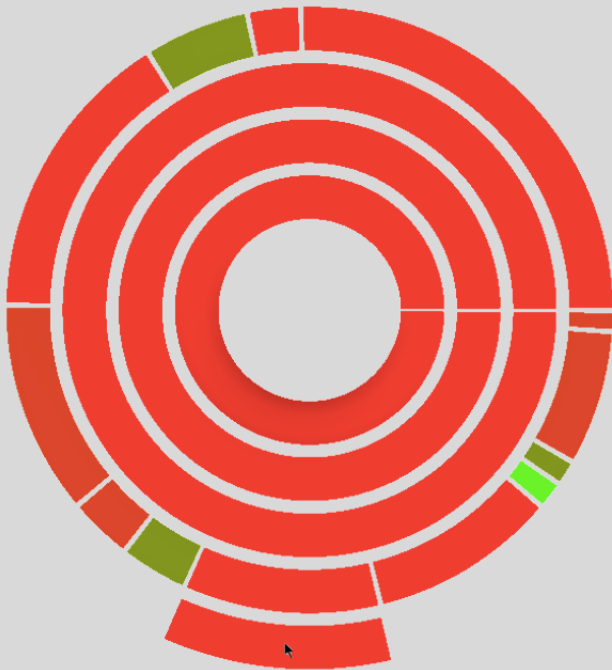
GZoltar



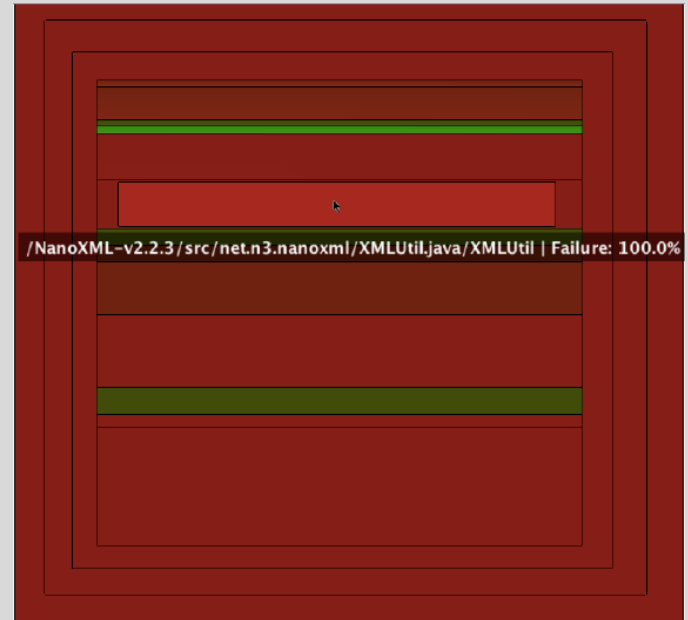
Low 
Suspiciousness

Medium 
Suspiciousness

Very High 
Suspiciousness



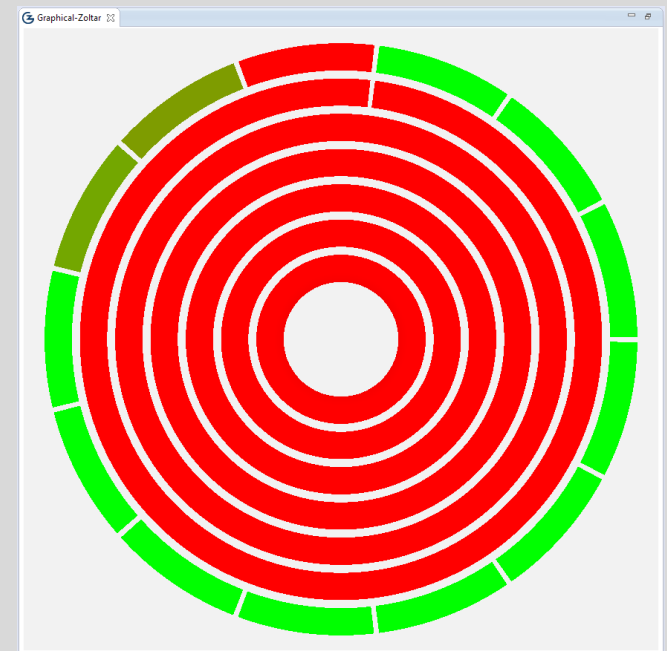
Sunburst



Treemap

| Ranking | S_o | Statement |
|---------|-------|--|
| 1 | 1.000 | 4: return NaN; /* FAULT*/ |
| 2 | 0.447 | 3: if (real == 0.0 && imaginary == 0.0) |
| 3 | 0.408 | 1: if (isNaN) |
| 4 | 0.000 | 2: return (NaN); |
| 5 | 0.000 | 5: if (isInfinite) |
| 6 | 0.000 | 6: return ZERO; |
| 7 | 0.000 | 7: if (FastMath.abs(real) < Fastath.abs(imaginary) |
| 8 | 0.000 | 8: double q=real/imaginary; |
| 9 | 0.000 | 9: double scale=1.0/(real * q + imaginary); |
| 10 | 0.000 | 10: return createComplex(scale * q, -scale); |
| 11 | 0.000 | 11: } else { |
| 12 | 0.000 | 12: double q=imaginary/real); |
| 13 | 0.000 | 13: double scale=1.0/(imaginary * q + real); |
| 14 | 0.000 | 14: return createComplex(scale, -scale * q);} |

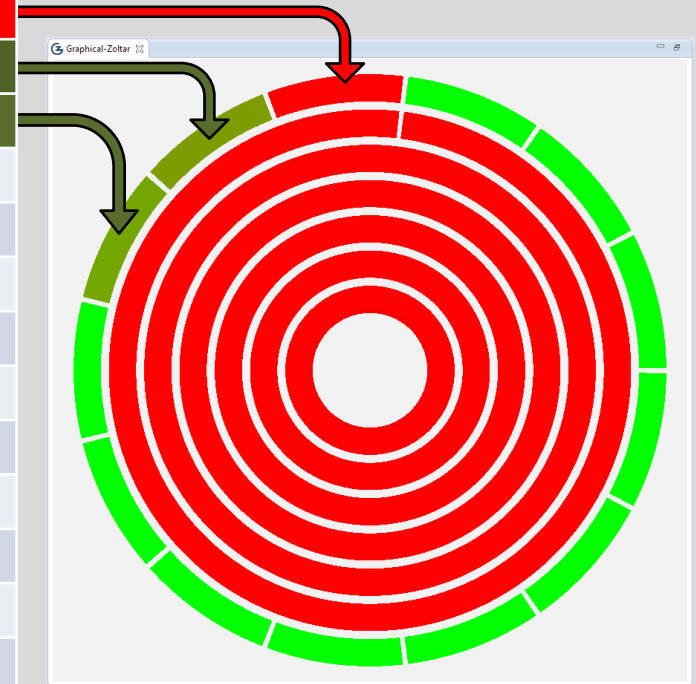
Suspiciousness ranking



Sunburst

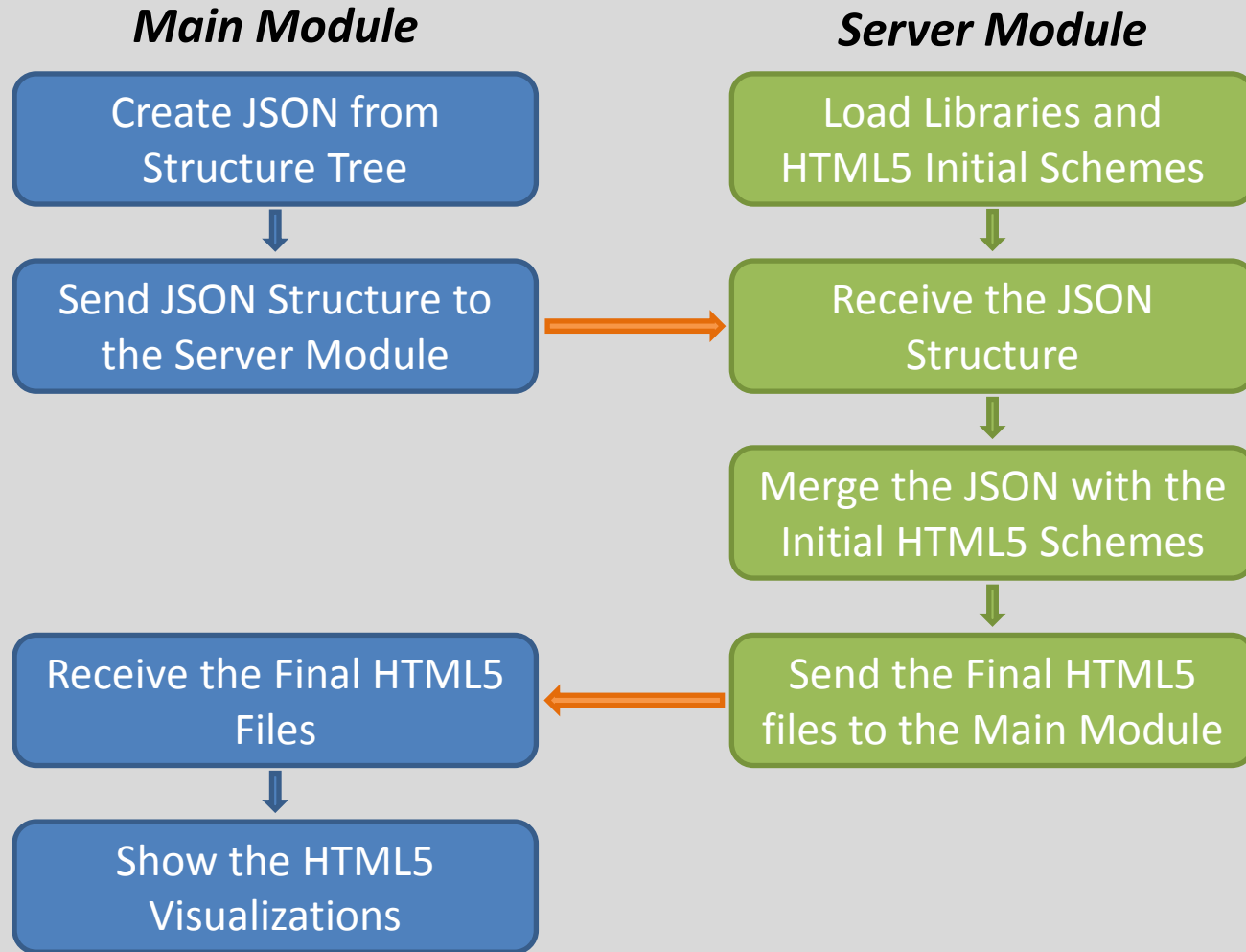
| Ranking | S_0 | Statement |
|---------|-------|--|
| 1 | 1.000 | 4: return NaN; /* FAULT*/ |
| 2 | 0.447 | 3: if (real == 0.0 && imaginary == 0.0) |
| 3 | 0.408 | 1: if (isNaN) |
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| 10 | 0.000 | 10: return createComplex(scale * q, -scale); |
| 11 | 0.000 | 11: } else { |
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Suspiciousness ranking

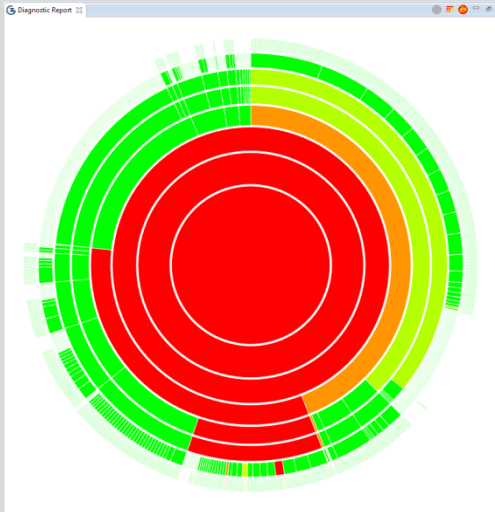


Sunburst

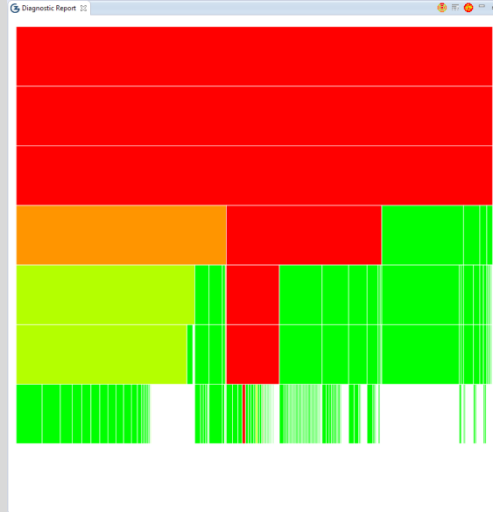
GZoltar's Workflow



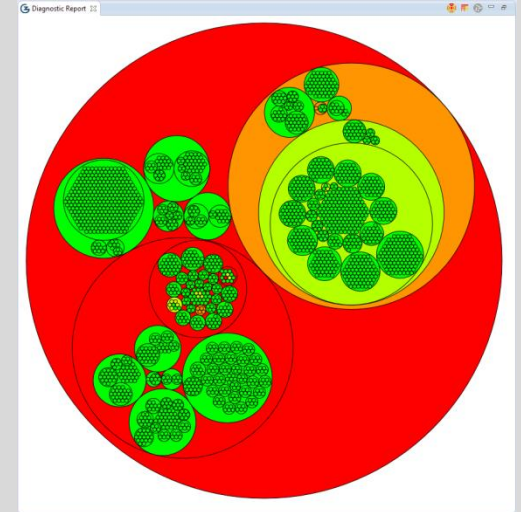
New Visualizations



Sunburst



Vertical Partition

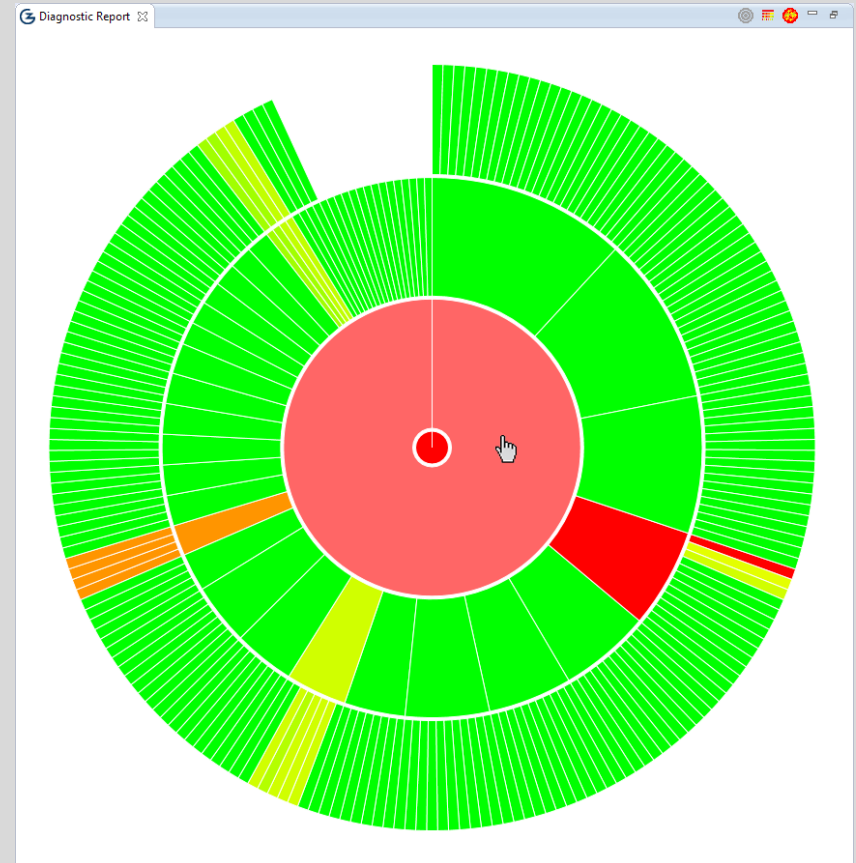
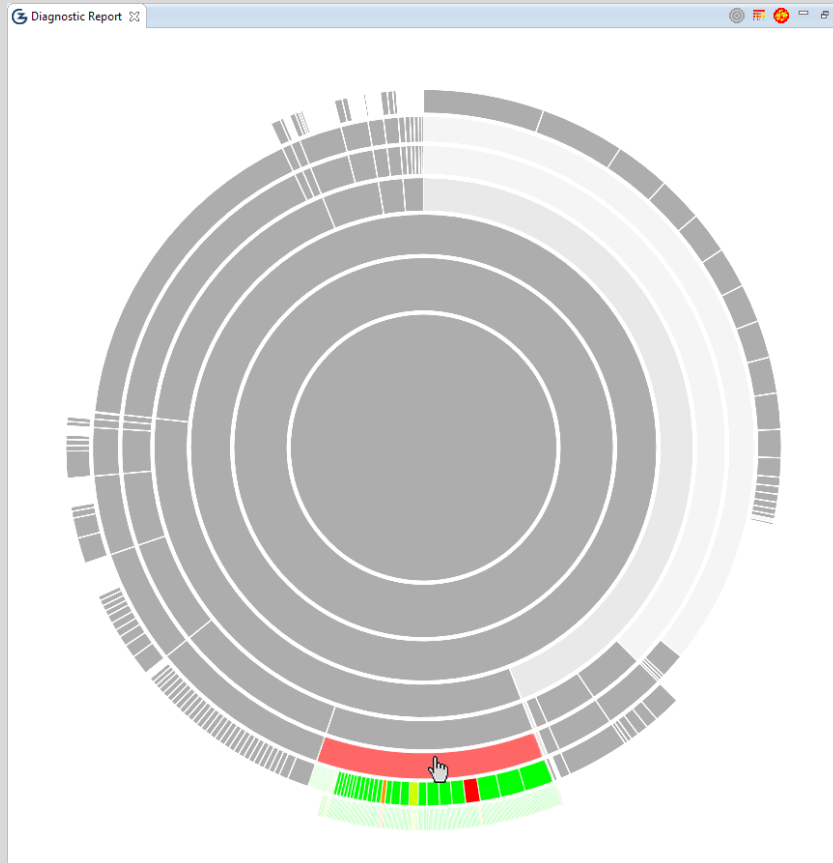


Bubble Hierarchy



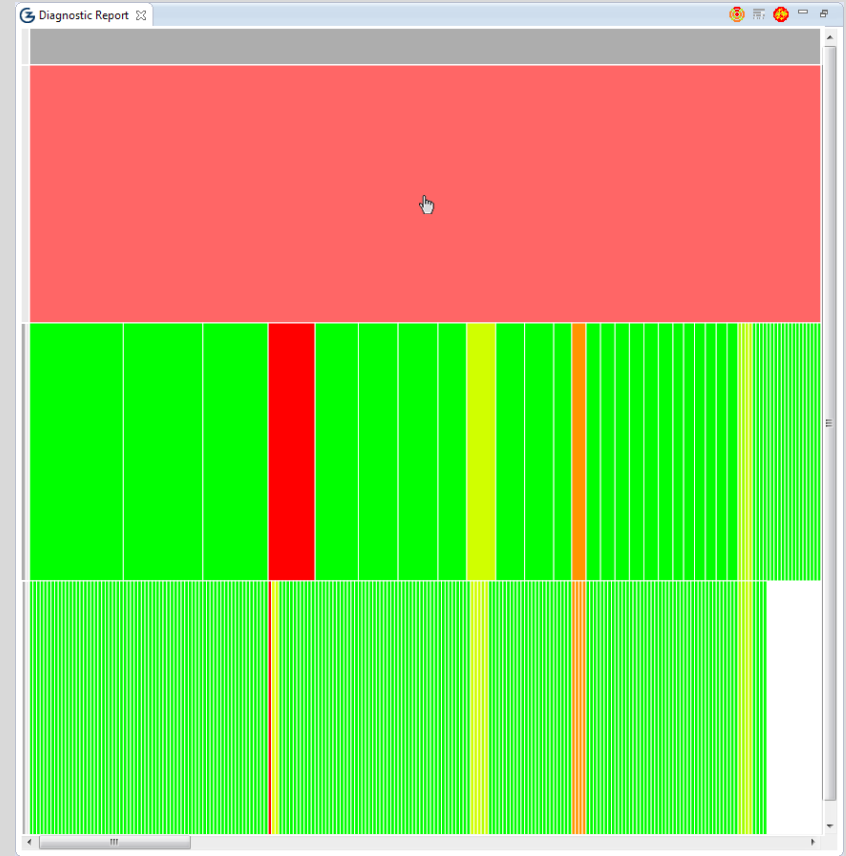
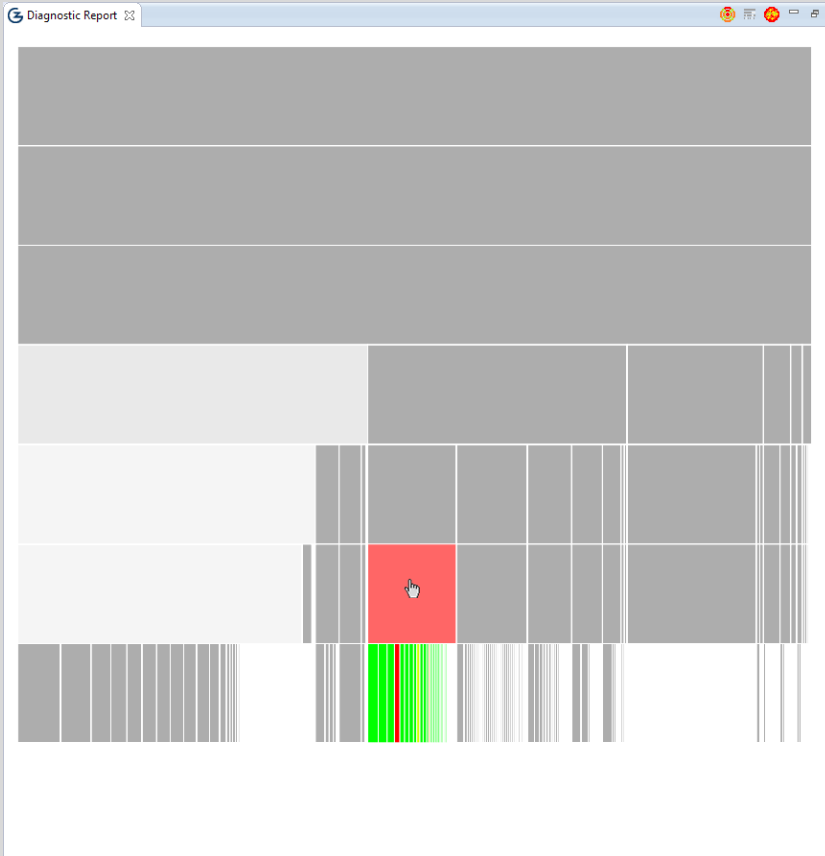
Gradient

New Visualizations – Sunburst



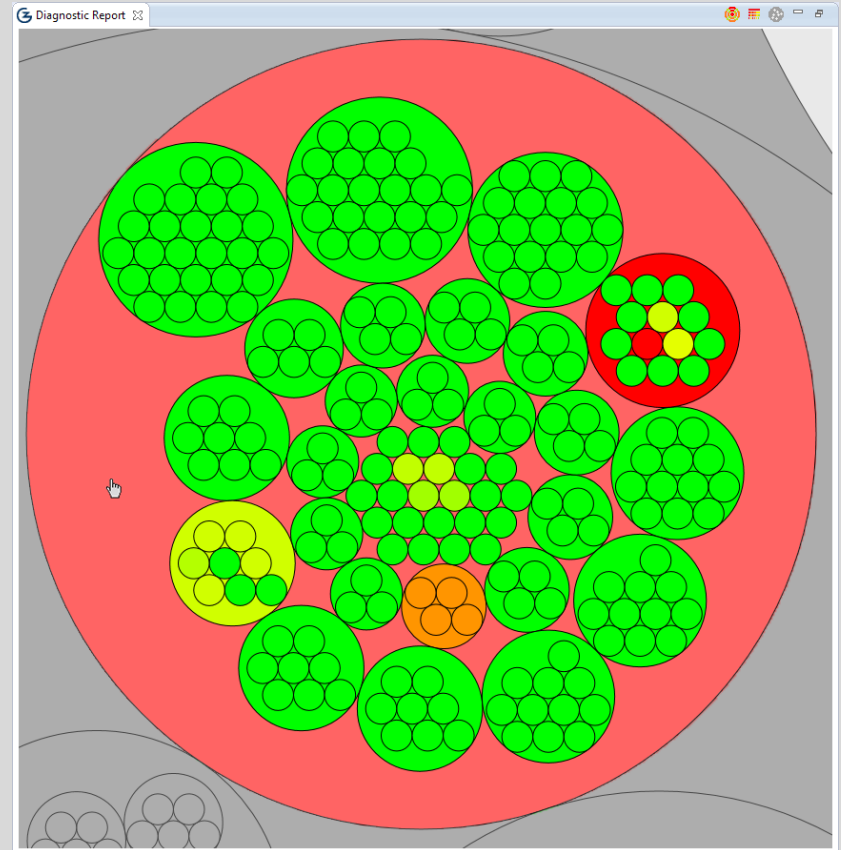
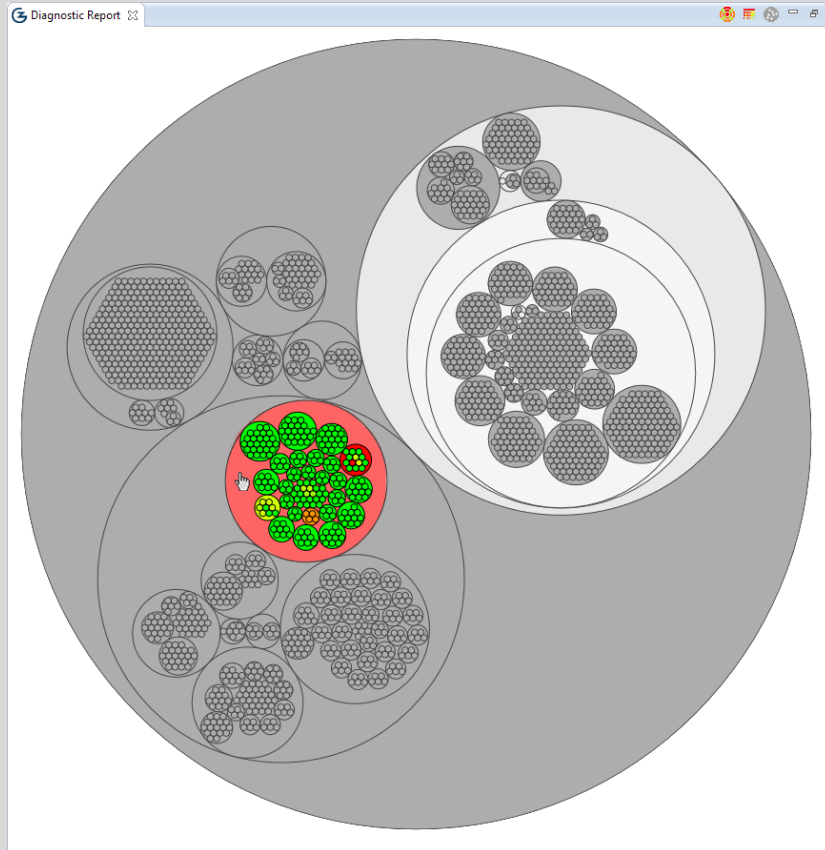
Root Change

New Visualizations – Vertical Partition



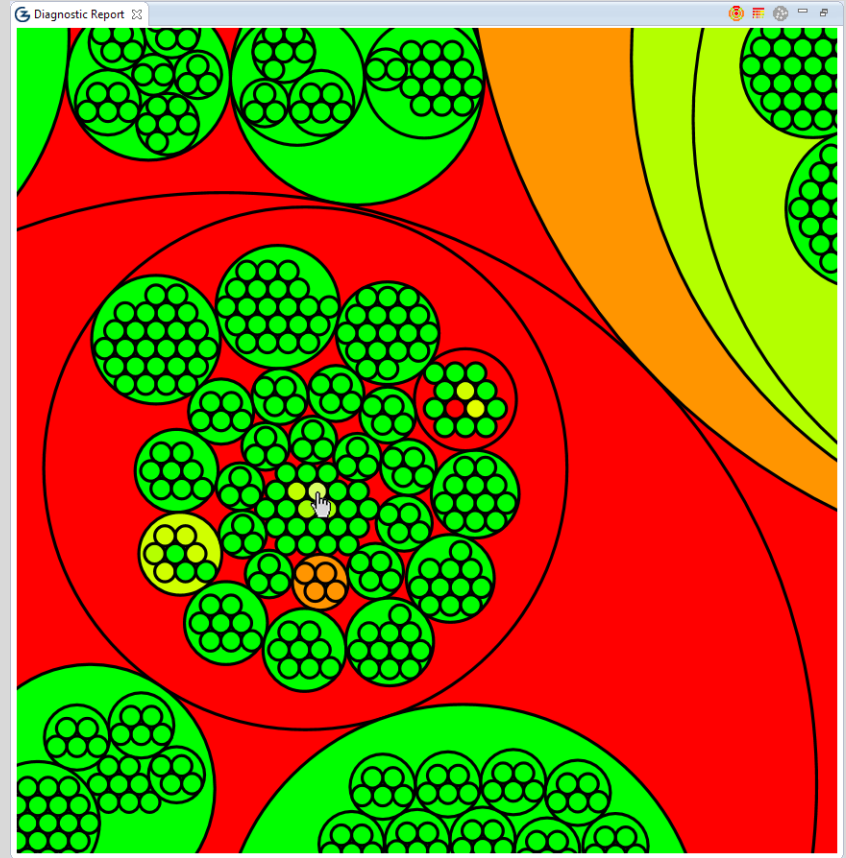
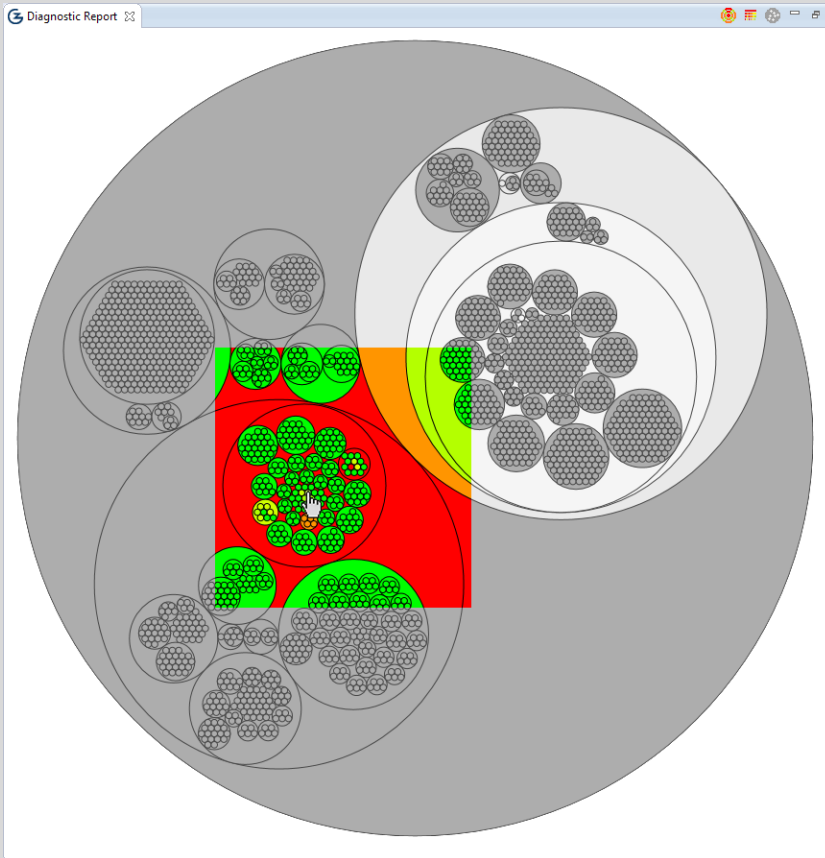
Root Change

New Visualizations – Bubble Hierarchy



Root Change

New Visualizations – Bubble Hierarchy



Zoom

New Visualizations

The screenshot displays the Eclipse IDE interface. The main editor shows the `Complex.java` file with the `reciprocal()` method highlighted. A black arrow points from the `reciprocal()` method in the code to a corresponding segment in a circular 'Diagnostic Report' visualization. The visualization consists of concentric rings with segments colored in a gradient from red to green. A tooltip at the bottom left of the visualization shows the file path: `/commons-math/src/org/apache/commons/math3/complex/Complex.java` and the method `Complex.reciprocal()` with a likelihood of 1.000.

The 'Diagnostic Report' visualization is a circular chart with concentric rings. The segments are colored in a gradient from red to green. A black arrow points from the `reciprocal()` method in the code to a corresponding segment in the visualization.

The 'Tasks' panel at the bottom shows a table with the following data:

| Set | Set Cardinality | Runtime (ms) | Failure Trace |
|--|-----------------|--------------|---------------|
| Set1 | 12 | 337 | |
| org.apache.commons.math3.RetryRunnerTest | 1 | 0 | |
| org.apache.commons.math3.complex.ComplexTest6 | 0 | 0 | |
| org.apache.commons.math3.complex.ComplexTest2 | 0 | 0 | |
| org.apache.commons.math3.complex.QuaternionTest | 90 | 108 | |
| org.apache.commons.math3.complex.ComplexUtilsTest | 2 | 0 | |
| org.apache.commons.math3.complex.ComplexFieldTest | 0 | 76 | |
| org.apache.commons.math3.complex.RootsOfUnityTest | 31 | 4 | |
| org.apache.commons.math3.complex.ComplexTest | 25 | 0 | |
| org.apache.commons.math3.complex.ComplexTest_BUG | 0 | 346 | |
| org.apache.commons.math3.complex.FrenchComplexFormatTest | 0 | | |
| org.apache.commons.math3.complex.ComplexTest5 | 14 | | |
| All Tests | | | |

Click and Jump

New Visualizations

The screenshot displays the Eclipse IDE interface. The main editor shows the source code of `Complex.java` from the `org.apache.commons.math3.complex` package. A tooltip is visible, listing suspiciousness scores for various classes in the package:

- 300 (Low)
- 301 (Low)
- 302 (Low)
- 303 (Medium)
- 304 (High)
- 305 (Very High)

The background shows the source code of `Complex.java` and the Outline view on the right, which lists the package's contents. The bottom of the IDE shows the Tasks view with a table of test results.

| Set | Set Cardinality | Runtime (ms) | Failure Trace |
|--|-----------------|--------------|---------------|
| Set 1 | 12 | 360 | |
| org.apache.commons.math3.complex.ComplexTest5 | | 0 | |
| org.apache.commons.math3.complex.ComplexFieldTest | | 1 | |
| org.apache.commons.math3.complex.ComplexTest3 | | 0 | |
| org.apache.commons.math3.complex.QuaternionTest | | 72 | |
| org.apache.commons.math3.complex.ComplexTest6 | | 0 | |
| org.apache.commons.math3.complex.ComplexTest_BUG | | 3 | |
| org.apache.commons.math3.complex.RootsOfUnityTest | | 58 | |
| org.apache.commons.math3.complex.ComplexTest | | 69 | |
| org.apache.commons.math3.complex.RetryRunnerTest | | 0 | |
| org.apache.commons.math3.complex.FrenchComplexFormatTest | | 34 | |
| org.apache.commons.math3.complex.ComplexUtilsTest | | 122 | |
| org.apache.commons.math3.complex.ComplexTest2 | | 1 | |
| All Tests | 14 | 371 | |

Low 
Suspiciousness

Medium 
Suspiciousness

High 
Suspiciousness

Very High 
Suspiciousness

User Study

- The aim is to answer to these two research questions:
 - **RQ1:** Do the proposed visualizations efficiently aid the user to quickly and easily find a fault?
 - **RQ2:** Is GZoltar a usable toolset?

User Study

- The goal was to find and fix an injected fault;
- **40 users** divided into 2 groups:
 - **20 users (control group)** performed without visualizations;
 - **20 users (test group)** performed with visualizations.

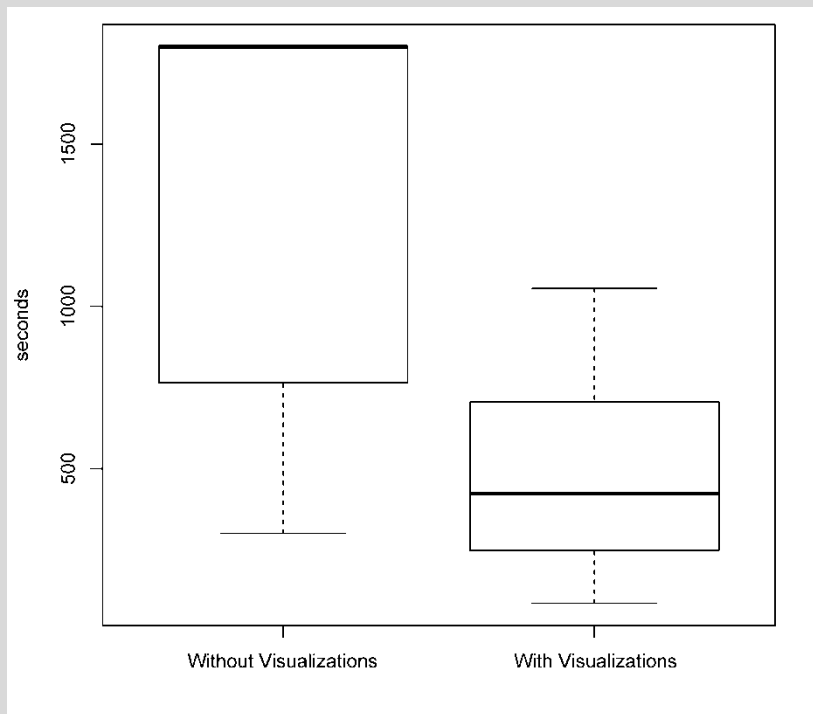
User Study

- **RQ1:** Do the proposed visualizations efficiently aid the user to quickly and easily find a fault?

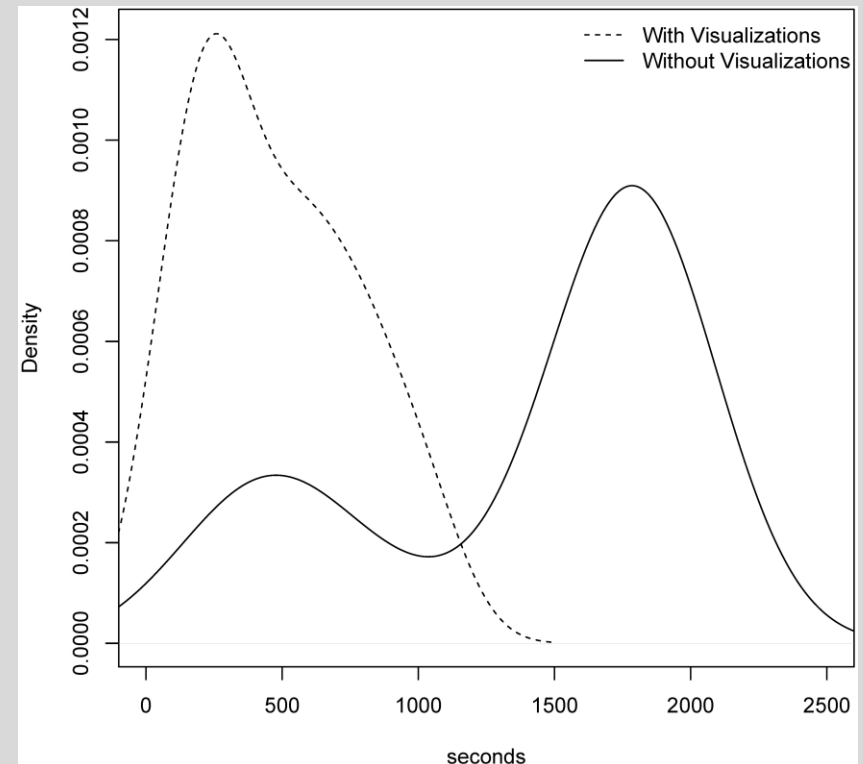
| - | Test Group | Control Group |
|--------------|--------------|-----------------|
| Found it | 100% | 35% |
| Average | 7min and 53s | 23min and 22s |
| Median | 7min and 3s | 30min (timeout) |
| S. Deviation | 4min and 52s | 9min and 49s |

User Study

- **RQ1:** Do the proposed visualizations efficiently aid the user to quickly and easily find a fault?



Time to find a fault



Times distribution

User Study

- **RQ1:** Do the proposed visualizations efficiently aid the user to quickly and easily find a fault?
 - The null hypothesis of the *t-test* was used to determine if two groups are significantly different from each other.
 - $H_0: \mu_2 \geq \mu_1$
 - μ_2 - **test group**
 - μ_1 - **control group**
 - We **refuted** this hypothesis and created an alternative hypothesis.
 - $H_1: \mu_2 + \Delta_x \geq \mu_1$
 - $\Delta_x = 9 \text{ minutes and } 17 \text{ seconds}$

User Study

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 - $\Delta_x = 9 \text{ minutes and } 17 \text{ seconds}$
 - $\Delta_x = 3 \text{ hours}$

User Study

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 - $\Delta_x = 9 \text{ minutes and } 17 \text{ seconds}$
 - $\Delta_x = 3 \text{ hours}$
 - $\Delta_x = 2 \text{ days and } 16 \text{ hours}$

User Study

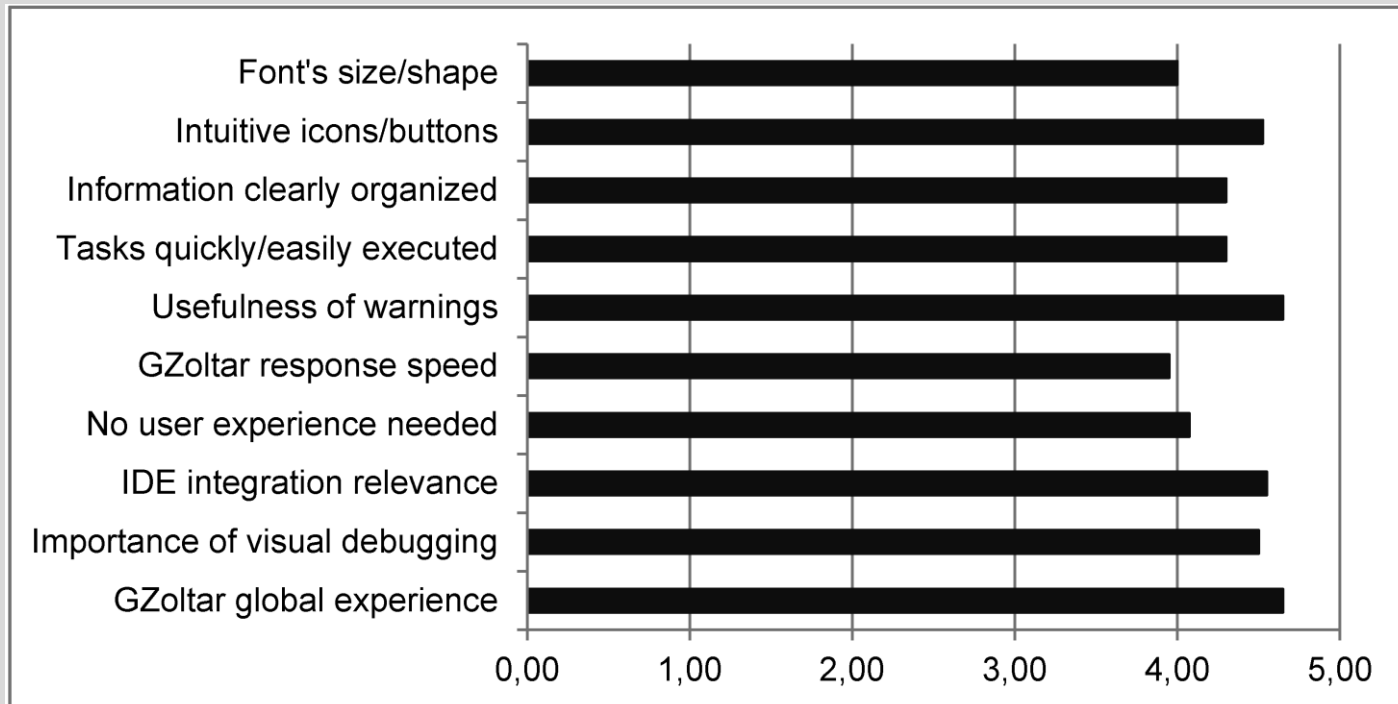
- **RQ1:** Do the proposed visualizations efficiently aid the user to quickly and easily find a fault?
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 - $H_1: \mu_2 + \Delta_x \geq \mu_1$
 - $\Delta_x = 9 \text{ minutes and } 17 \text{ seconds}$
 - $\Delta_x = 3 \text{ hours}$
 - $\Delta_x = 2 \text{ days and } 16 \text{ hours}$
 - $\Delta_x = 11 \text{ days and } 10 \text{ hours}$

➤ **RQ2:** Is GZoltar a usable toolset?

- After the debugging task, the test group was invited to answer a questionnaire, and their answers revealed that GZoltar is a usable toolset.
- The answers were given as a Likert scale, from 1 to 5, where 1 means nothing favourable and 5 means very favourable.

User Study

➤ RQ2: Is GZoltar a usable toolset?



Average classification per topic

➤ **RQ2:** Is GZoltar a usable toolset?

- We calculated also a correlation coefficient, and we found a strong correlation between:
 - intuitive icons/buttons and information clearly organized;
 - intuitive icons/buttons and usefulness of warnings;
 - intuitive icons/buttons and tasks quickly/easily executed;
 - information clearly organized and IDE integration relevance;
 - no user experience needed and GZoltar global experience.

Conclusions

- The main contributions of this thesis are:
 - The set of HTML5-based visualizations to display information-rich diagnostic reports.
 - An user study, showing the benefits the visualizations bring to the debugging phase.
 - The creation of two separated modules;
- Along the way contributions:
 - A new gradient;
 - A new warning added;

Conclusions

- Visualizations aid the software debugging process;
- The features of each one enable a faster and easier way to found the faults;
- The interaction options in the GZoltar toolset are intuitive and easy to learn, which makes it an efficient and effective toolset;
- HTML5 resolved our implementation OpenGL issues.

Future Work

- New features:
 - Select an element and hide automatically all the others or just change its colours to a grey scale to not disturb the user attention;
 - Possibility of selecting some test cases of the analysed software system and represent only the affected components by them.
- 3D visualizations;
- Porting of the entire toolset to other IDE's, such as IntelliJ IDEA and Visual Studio.

Publications

- Carlos Gouveia, José Campos and Rui Abreu. **Support Software Fault Isolation with HTML5 Visualizations** – accepted into *The 6th Meeting of Young Researchers of University of Porto (IJUP'13)*, 2013.
 - This paper outlines the idea of using new interactive HTML5 visualizations to support software fault isolation and performing an user study to evaluate the benefits of this association.
- Carlos Gouveia, José Campos and Rui Abreu. **Using HTML5 Visualizations in Software Fault Localization** – accepted for publication in the Proceedings of the *1st IEEE Working Conference on Software Visualization (VISOFT'13)*, former IEEE International Workshop on Visualizing Software for Understanding and Analysis (VISOFT) and ACM Symposium on Software Visualization (SOFTVIS). September 27-28, 2013, Eindhoven, the Netherlands.
 - This paper presents and explains the HTML5 visualizations and the GZoltar interaction, and an user study.

Questions

